Public Safety Video Surveillance over 3GPP Mobile Broadband

January, 2010

Introduction

- In many public safety applications, there is a strong focus on the use of the mobile broadband network to support mobile and portable video surveillance
- Video is the most demanding application on a public safety mobile broadband network
  - Applications for video on both downlink and uplink
- Uplink video needs the most careful consideration
  - Just a few mobile cameras at high video data rates can saturate a sector's capacity
  - Network has to be designed to support individual cameras at the cell edge

Mobile & Fixed Video Surveillance

- 3GPP Rel 7 and Rel 8 mobile broadband designed from the outset for mobility
  - Supports devices traveling at speeds >80 mph
  - Efficient Inter-cell handover

- Mix of mobile and fixed applications possible
  - Permanent cameras
  - Ad-hoc surveillance network (special events, crises, etc.)
  - Vehicle “dashboard” mounted cameras
  - Aeronautical surveillance (helicopter, low flying aircraft)
  - Body-worn cameras (“helmet cams”, etc.)

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Optimization of a 3GPP Network for Uplink Video

- Several techniques, often used in combination
  - Chose a release that delivers highest uplink average sector throughput (average throughput determines how many cameras can be supported at a given rate)
    - Rel 8 LTE or Rel 7 TD-CDMA preferred
  - Use the most advanced uplink interference mitigation techniques
  - Use cameras with advanced video codecs (medium to high compression) and intelligent video features (see following slide)
  - Use local camera storage, for FTP download of evidential quality video
  - Activate mobile (e.g. police car) cameras only when needed (e.g. at an incident or traffic stop)
  - Engineer installations of UE's supporting cameras to maximize the modulation and coding format used – allows each camera to use less sector resource
    - Use vehicle roof-mounted high gain omni antennas for mobile installations
    - Use high gain omni or directional antennas, mounted high, for portable and fixed cameras

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Surveillance Technology Advancements

- Advancements in network camera technology significantly expand functionality of surveillance network
  - Advanced Video Codecs (MPEG-4, H.264)
  - Intelligent Video (Motion Detection, etc.)
  - Local Camera Storage
- Reduces video bandwidth requirement without sacrificing video quality
  - Per-camera bandwidth as low as 128kbps can deliver good quality for video surveillance
- Enables operator to support more cameras per sector

Intelligent Video

- Video applications that are mindful of the network capacity

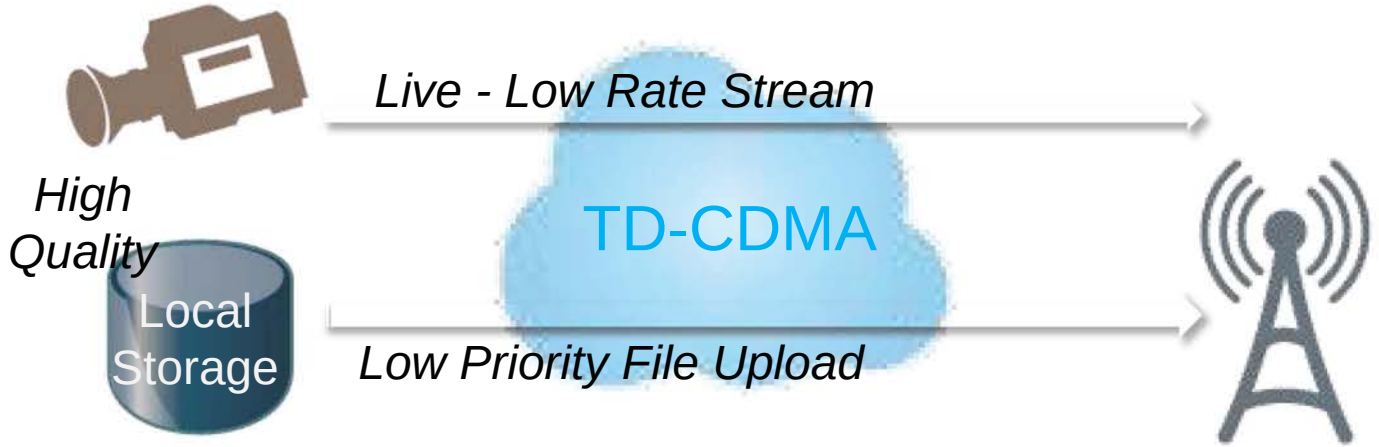
- ***Problem***: Typically too much video is recorded for anyone to ever monitor or search
- ***Solution***: Latest network cameras can have standard event detection and alarm management algorithms
  - Purpose-built, highly integrated hardware that excels in image analysis tasks
  - Camera decides when to send video, what frame rate and resolution, and when to alert a specific operator for monitoring and/or response.

- Intelligent Functions:
  - Motion Detection
  - Tampering Alarm
  - Automatic Number Plate Recognition (ANPR)
  - Indentify/Facial Recognition
  - People counting
  - Object tracking, etc.

- Intelligence at the camera level reduces surveillance traffic load & enables a more productive and effective means of surveillance

Local Camera Storage

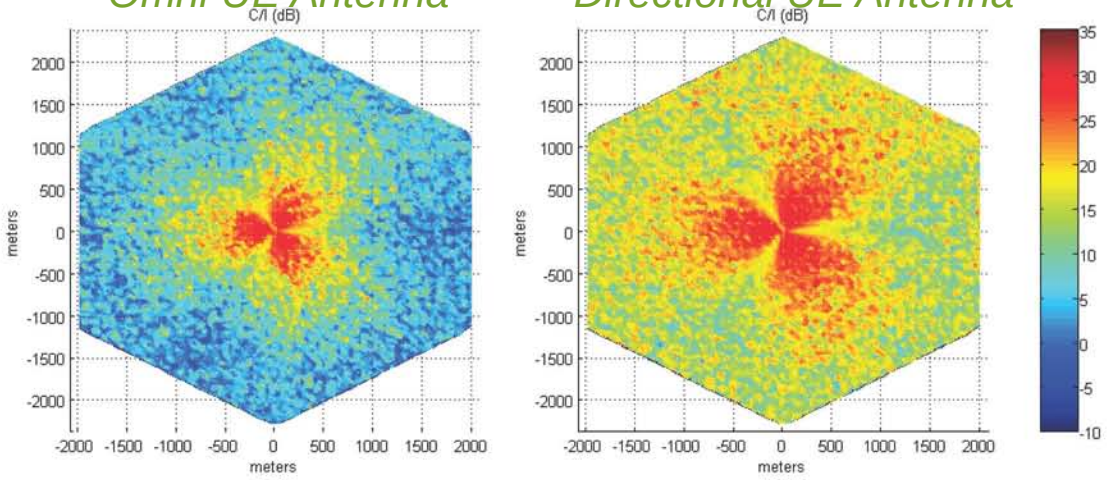
- Local camera storage combined with intelligent video significantly reduces per-camera bit-rate requirement
- Stream live low rate surveillance quality continuously over network
  - Option to increase live stream bit-rate upon event detection or user decision
- Store high rate evidential quality video locally at camera
  - User or event trigger can initiates upload recorded video footage to be reviewed
  - Control consumed bandwidth of upload using QoS mechanism to adjust relative priority of uploads and live streams



Fixed Cameras w/ Directional Antennas

- Cellular networks typically suffer from diminishing cell edge performance
  - Due to interference from neighboring cells in interference limited network
- Solution: Fixed cameras deployed with directional antennas
  - Beamwidth, Gain & Front-to-Back Ratio reduces interference
  - Improves signal quality, C/I
  - Achieve higher throughputs across coverage area

Omni UE Antenna *Directional UE Antenna*



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Directional UE Antennas

- Overshoot effect caused by using high gain directional antennas in cellular network

- Mitigate overshoot via:
  - Intercell Interference Cancellation
    - Node-B uses inter-cell interference cancellation (Rel 7 TD-CDMA) to cancel the strongest interferers from neighboring cells
  - UL Power Control
    - Limits transmit power to level necessary to close link at desired throughput
    - Minimizes the interference seen by neighboring cells.

Camera Bandwidth Determination

- Number of cameras per sector dependent on video bandwidth requirements
  - Video bandwidth from 128kbps to >2Mbps all possible
  - Dependant on frame rate, resolution, codec, etc.
  - 128-512 kbps is practical balance between finite capacity, number of cameras per sector, and video quality
- Example video parameters & resulting video bandwidths:
  - Results assumed the use of MPEG-4 compression
  - Video BW assumes level of movement & lighting typical of traffic intersection

Frame Rate (fps)	Resolution	Compression	Video BW (kbps)°
12	480x270	Medium	128
18	320x240	Medium	128
18	480x360	Medium	256
30	480x360	Medium	512
30	640x480	Medium	1024
30	1280x960	Medium	2048

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Sector & Site Camera Capacity

- For low bit rate cameras, average sector throughput determines number of cameras that be supported by a sector
  - Assumes uniform distribution of cameras
- LTE Average Sector UL Throughput (Capacity): **3.8Mbps (approx)**
  - 5+5 MHz N=1 System
  - Mobile Users
- Capacity assuming only fixed users is approximately double
  - Use of directional antennas. Higher gain. Interference reduction.
- Example shown assumes all UL capacity used for video surveillance.
  - Results scale for less than 100% usage

# of Cameras:	per Sector		per 3-Sector Site	
Video BW (kbps)	Mobile	Fixed	Mobile	Fixed
128	30	59	90	177
256	15	30	45	90
512	7	15	21	45
1024	4*	7	12	21
2048	2*	4	6	12

* Included for completeness, but Avg. Sector Throughputs not directly applicable.

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Cell Edge Uplink Video Support

- For public safety applications, support of mobile / portable video surveillance anywhere in the network is essential

→ *Requires that the camera video data rate matches the cell edge uplink per-UE rate that the network is designed for*

- LTE 5+5 MHz public safety networks would typically be designed for a cell edge user rate of 128 kbps or 256 kbps

→ *Recommend camera rates of 128 or 256 Kbps according to network design*

  - This also maximizes the number of cameras that can be supported per sector
- Fixed cameras can operate at higher cell edge rates
  - See slides 8 and 9

Downlink Video

- Clear operational benefits in transmitting video gathered from multiple sources to field officers (i.e. controlled by dispatcher), using the mobile broadband downlink
- Sources such as: uplink video from the network, fixed and portable cameras, helicopter video

Command Center

"Robbery in Progress"

Vehicle Units

Local Map

Foot Patrols

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Downlink Video Solutions

- Multicast – common video feed to all subscribing users in a sector
- Multicell broadcast – to all subscribing users across the network
  - Most efficient due to multi-cell constructive combining in UE receiver (see following slide)
  - Use 3GPP Rel 6 TDtv or Rel 7 Integrated Mobile Broadcast (IMB)
  - No support in Rel 8 LTE (possible in later releases)
- In-band broadcast on same spectrum as mobile broadband
  - Supported by TDtv on Rel 7 TD-CDMA
    - "*n*" timeslots allocated to broadcast only when required
- Out-of band-broadcast – separate RF channel
  - Supported by IMB
  - Feasible to operate at a higher frequency, as multi-cell constructive combining increases link budget relative to mobile broadband network

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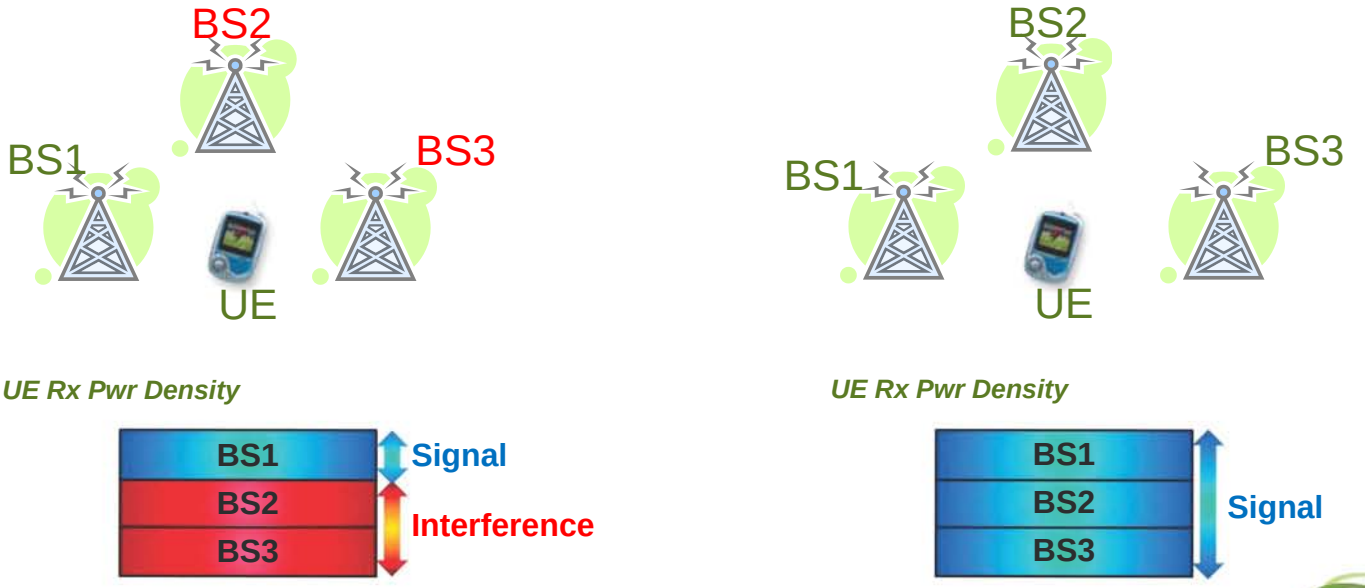
MBMSFN – 3GPP TDtv and IMB

- **M**ultimedia **B**roadcast **M**ulticast **S**ervice over **S**ingle **F**requency **N**etwork
- All BS are synchronised and transmit the same signal waveform
- UE combines signals from multiple cells as a natural part of the equalisation process ⇒ increases captured signal power & reduces interference levels
- Cell edge UE "sees" more neighbour BS ⇒ benefits from signal combining
- High C/I can be achieved throughout the cell for high quality multimedia service
- Very spectrally efficient for Broadcast (MBMS)

Unicast vs. SFN Broadcast



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